



850 Pasquinelli Drive • Westmont, Illinois 60559-5539  
630-887-7100 • Fax: 630-887-7417

## **FORENSIC HAIR COMPARISONS: GUIDELINES, STANDARDS, PROTOCOLS, QUALITY ASSURANCE AND ENFORCEMENT**

Presentation

To

The National Academies Committee on Identifying the Needs of the Forensic Sciences Community

By

Richard E. Bisbing

McCrone Associates, Inc.

Westmont, IL

April 24, 2007

### **INTRODUCTION**

You invited me to speak to the following topics:

- The process for establishing the guidelines and standards for hair analysis
- The standards, guidelines and protocols for hair analysis
- Quality assurance and enforcement of standards for hair analysis
- Any recommendations for hair analysis
- What is needed for hair analysis?

I am pleased to do just that.

### **HAIR AS EVIDENCE**

I would like to introduce my presentation with three cases from my career that illustrate the importance of hairs as evidence, cases in which there was no DNA.

(1) A sexual assault took place in a college dorm. The blonde victim identified four African American men as her assailants, although she thought that only one may have penetrated her. Only one of the men had a blond pubic hair entangled in his own pubic hair and a foreign black pubic hair recovered from the victim's pubic combings was microscopically similar to the same man's pubic hair and unlike the hairs from the other three men.

(2) A fatal car crash resulted in the death of one of two occupants; of course, the survivor claimed the deceased was the driver. Hairs were found up in the right front corner of the windshield next to the A pillar. Accident Reconstructionists determined the spin of the vehicle during the crash and that the hairs on the right A pillar were likely from the driver. Fabric impressions across the console from the driver's seat toward the right front of the passenger compartment confirmed the occupant kinematics. The hairs on the

windshield were similar in all respects to the survivor and dissimilar to the deceased's head hair, thus pointing to the survivor as the driver of the vehicle.

(3) A dry cleaning establishment was robbed at gun point. After obtaining the money, the robber forgot to take his dirty clothes with him. The dirty clothes were covered with dog hairs. When a suspect was developed, his dog helped confirm the eyewitness identification.

These cases are simple illustrations of how hair can be used as associative evidence; there have been thousands of similar cases in the last 100 years. In the past, the number of hair cases always has been greater than any other type of trace evidence. There are three good reasons for their prevalence and potential value.

(1) They illustrate in many ways the role of the criminalist as described by Paul L. Kirk more than fifty years ago.

- Criminalists supply leads such as the hair color and racial origin of the likely assailant.
- Criminalists reconstruct events by showing contact with parts of a crime scene, accident scene or weapon.
- Criminalists develop suspects by comparing evidential hairs with possible suspects.
- Criminalists check statements by checking alibi samples.
- Criminalists eliminate suspects whose hair does not match hairs found on a victim's body.
- Criminalists substantiate probable guilt of defendant by associating hairs with defendants.

(2) When a crime scene investigator or detective brings a suspected hair to the crime laboratory, they might ask: What can be learned from examination of this suspected hair that might help me with my investigation? I'd tell them: we can probably answer the following questions.

- Is the fiber a hair, textile fiber or what?
- If a hair, is it human?
- If animal hair, what kind of animal?
- Could it be from a wig?
- What is the racial origin?
- What is the somatic origin?
- Is it long or short, black or blond?
- Was the hair broken, crushed, or cut?
- How was it cut?
- Was the hair singed?

- How had it been treated, bleached, dyed?
- Has it laid there awhile?
- Was it forcefully removed?
- Is it a foreign hair?
- Might it have probative value?
- Could it have originated from the suspected source?
- Is it a source of DNA?

(3) Hairs have a number of innate qualities that make them useful as trace evidence.

- Hair is personal evidence originating directly from the individual
- Hair is continually falling from the body.
- Hair is easily detected, recovered and preserved.
- Hair is persistent and not easily destroyed.
- Hair is hard to hide or to throw away.
- Hair is relatively unchanging over time.
- Hair varies from person to person.
- Hair contains DNA.

## **DNA EXONERATIONS**

The Innocence Project and other similar post-conviction exonerations using DNA have revealed a problem with hair evidence. Out of 198 exonerations, The Innocence Project identified 38 cases in which there were hair associations introduced at trial. I have consulted on at least four of them and from those cases I have noticed that they have a few things in common. Please give me some slack, I understand that these commonalities are probably oversimplified and generalized too much; but, I think they illustrate the problem.

- Each hair examiner lacked on-the-job training, mentoring, supervision, and colleagues with whom to consult; some claimed their only training was a one week course at the FBI Academy; and most worked alone.
- Each had extensive experience; many cases were handled, reported and testified about, usually for longer than a decade.
- Each was given little time, just before trial, to complete the comparisons; it is too late to decide that relevant hairs came from someone other than the defendant a year or more after the arrest and just weeks before trial.
- Each knew the questioned and known hairs differed, either by evidence in their own notes or by the fact that one of their colleagues had already said they did not match.
- Each was in disagreement with a peer reviewer, or at least a defense expert.

- Each ignored the alibi samples from other suspects or defendants, or did not eliminate the victim, or tried to examine the hair samples from another suspect in the hallway before trial.
- Each relied solely on microscopical comparisons, which was the state-of-the-art at the time.
- Finally, each became a hero in the eyes of the prosecutor by finding a match and helping to secure a conviction.

These cases seem to be contrary to some basic tenets proffered 30 years ago.

- Hair examiners must be properly and thoroughly trained.
- Hair examiners must have extensive experience.
- Hair examiners must be allowed time to reach a decision.
- Hair examiners must be allowed inconclusive results.
- Hair examiners must be allowed access to background information from the case.
- Hair examiners must be allowed to consult with a colleague.

## **HAIR COMPARISONS**

For more than 100 years, microscopical hair comparisons have been relied upon to provide possible associations or exclusions between a recovered hair and known sources of hair. This has been the case even though conclusions from a microscopical comparison regarding the donor of the hair are, by necessity, equivocal, that is “could be evidence.”

By comparison, we know that nDNA yields a virtual positive association to an individual. Because of the strength of the nDNA comparison, it is considered by many laboratories to be a preferred and sufficient method for hair examination. As powerful a tool as nDNA analysis is in establishing the potential source of a hair, it does not provide other facts that might be important to the investigation. For example, establishing the presence of a victim’s head hair on a tool belonging to a spouse does not have the same significance as finding numerous head hairs that exhibit crushing on the tool. Finding the victim’s hairs in the trunk of the spouse’s car would not be unusual unless they were determined to have putrid roots proving they were deposited some time after death. Unfortunately, most hairs found at crime scenes do not possess sufficient root tissue to demonstrate a nDNA profile, anyway.

The overwhelming majority of hairs found in forensic casework do not possess enough nucleated tissue to conduct nDNA analysis. Fortunately, mtDNA is found in abundance in the hair shaft. We know mtDNA is maternally inherited; therefore all maternal relatives have the same mtDNA type. Furthermore, some individuals who are not closely related or apparently unrelated may also exhibit the same mtDNA type. A microscopical comparison of the hairs can differentiate between the hairs from various family members.

In one case, hairs were found on a bandana left at the crime scene by a robber. mtDNA was extracted from them which matched the defendant. The DNA laboratories had described the hairs from the bandana as red and the defense attorney noted that the defendant, a young African American male, did not have red hair. Subsequent microscopical study of the hairs from the bandana demonstrated them to be bleached. The defendant had never bleached his hair. Therefore, the hairs could not have originated from the defendant. It is particularly important to realize that microscopical examination and mtDNA analysis are complementary techniques; the strongest possible association is made by first comparing the physical aspects of the hair through microscopy, then by comparing the genetic aspects of the hair through mtDNA analysis. Eliminating the microscopical examination of hairs is, in my opinion, irresponsible because hairs can be so valuable in some of the most heinous crimes; therefore, hairs should not be ignored. Hairs should be treated as something of value, something honored in the laboratory. Instead, hairs have been deemphasized as evidence, thereby minimizing a means to solve crime, investigate deaths and protect the public.

There is another problem. Most people do not like comparing hairs; there are too many to compare and they are too hard to do; hair cases take too much concentration. The solution to the problem is an understanding by everyone of the value and importance of hair as evidence. Like Plato said, "What's honored in the country will be cultivated there."

DNA might be blamed for minimizing hair evidence, or at the very least DNA has sucked the moisture out of the trace evidence laboratories by absorbing up all the funding. As a consequence, a generation of forensic hair examiners has withered or been promoted to management. To grow another generation will require training and standards; but, like all new generations, they will be smarter than their predecessors because they will have access to the DNA laboratory.

Ironically, DNA also provides the nutrients for growth, the key to standards and enforcement of proper hair comparison, and the use of hair as evidence again. DNA provides the means to check the progress of an examiner trainee and help the examiner trainer understand significant differences between hairs. Through the use of DNA, hair examiners can be confident of their findings, build confidence in the users of trace evidence, minimize inconclusive results, and stand tall again out in the sunlight.

When compared to DNA, hair evidence has been criticized as being too subjective, lacking a scientific basis or scientific rigor, and lacking appropriate guidelines for its use. In reality there have been published guidelines for the identification and association of human hairs since 1985.

## **THE COMMITTEE ON FORENSIC HAIR COMPARISONS**

The idea of forming a committee to advance forensic hair comparison arose during discussions at Inter/Micro-82, a conference sponsored by the McCrone Research Institute in 1982. An ad-hoc committee was formed with Barry Gaudette as Chairman. Symposia were hosted by the FBI in 1983 and 1984 to support the work of the committee. A *Preliminary Report—Committee on Forensic Hair Comparison* was published by the FBI in 1984. The Committee's work culminated in An International Symposium on Forensic Hair Comparisons at the FBI Academy in 1985. The *Proceedings* included papers and reports describing recommendations for the comparison of human hair. The recommendations published in 1985 are not materially different from the current SWGMAT Guidelines, except with regard to DNA.

I know the process for establishing these guidelines has not changed; I sat through it twice, twenty years apart. It involves a nit-picking process of describing what we believe to be the best way to compare hairs until a consensus is reached. By we, I mean an international group of experienced hair examiners from local, state and federal forensic laboratories, academia, and commercial laboratories from the United States, Canada, Europe and Australia.

## **SWGMAT**

The Scientific Working Group for Materials Analysis (SWGMAT) Hair Committee was formed in 1996. Their work has resulted in consensus guidelines for hair comparison protocols and training. Current SWGMAT Guidelines are published in *Forensic Science Communications*. Hair Comparison Guidelines were completed and published in 2005; training guidelines are drafted awaiting final acceptance. An atlas of human hair characteristics and traits was compiled three times but never published; although atlases have been published by others in the interim.

The principal recommendation of SWGMAT is that DNA analysis can be performed on hair but should be performed only after an initial microscopical assessment. A full and detailed microscopical comparison with possible known sources of hair should be done prior to DNA analysis. DNA analysis should always be considered in those cases where the source of a hair is crucial to an investigation.

## **HAIR TRAINING GUIDELINES**

The SWGMAT training manual, although not yet adopted or published, is intended as a guide for use by laboratories responsible for training forensic hair examiners to prepare them to perform microscopical examinations. Suggestions as to lessons, reading assignments, practical exercises, progress monitoring, and trainee evaluation are included. The recommended training period is approximately one year, full time, for an

inexperienced forensic examiner. Each trainee should be trained by and work under the guidance of one or more experienced forensic hair examiners.

The trainer may be responsible for:

- Introducing the trainee to the relevant scientific literature, proper procedures, training material, and reference collections
- Discussing readings and theory with the trainee
- Teaching basic methods
- Teaching case management
- Fostering ethical and proper professional conduct through discussion and by setting an example
- Teaching appropriate quality assurance and quality control procedures
- Reviewing tests, practical exercises, and casework samples with trainee
- Teaching expert testimony skills through moot court and/or observation

The trainee is expected to meet the objectives set forth in the training program by:

- Self-study of reading materials
- Practicing of basic skills
- Using practical exercises
- Successful completion of written and oral tests
- Observation of case work being conducted by an experienced examiner
- Observation of court testimony given by an experienced examiner
- Conducting themselves in an ethical and professional manner
- Participating in the quality assurance and quality control program of laboratory
- Successful completion of competency tests in identification and comparison
- Competent performance of supervised casework
- Demonstrate ability to accurately and effectively communicate hair findings in court through court testimony monitoring and/or transcript review

The laboratory is responsible for maintaining:

- An up-to-date training program
- Documentation of competency tests and proficiency tests
- Documentation of court testimony

When the trainer, trainee, and supervisor conclude that the trainee is competent and sufficiently practiced, the trainee can proceed to supervised casework. The trainer or case supervisor must verify all laboratory results obtained by the trainee. At the end of the training program, the trainee should be ready to analyze cases and compare hairs independently. The results should then be peer reviewed in accordance with laboratory quality assurance procedures.

## HAIR COMPARISON GUIDELINES

SWGMAT guidelines include:

- a summary of techniques for collecting hair samples
- a description of the instrumentation used in the microscopical examination of hair
- a description of the microscopical examination
- a discussion on how to interface with subsequent DNA analysis of hair
- a discussion of the conclusions that result from the microscopical hair examination

Consistent with a need to know something of the case background, known samples may be requested from all persons who might reasonably be considered a source of a questioned hair. All associations are provisional. If such samples are obtained and excluded as the source of the questioned hair, the significance of any ensuing association is increased. The necessary equipment is described in some detail. Finally, there are guidelines for documentation and report writing. The examiner's notes should accurately reflect macroscopical and microscopical observations and results that lead to the examiner's conclusions. They should identify the questioned hairs, including both the associated and eliminated questioned hair specimens.

The guidelines define the possible conclusions from a hair comparison. The examiner should consider what meaning can be attached to an exclusion or association based upon the known case circumstances. Probabilities and population statistics should not be used in the interpretation of microscopical hair comparisons. Databases, from which population statistics can be generated, as is done in DNA analysis, are not practical or realistic.

If significant differences exist in the macroscopic and/or microscopic characteristics exhibited by the questioned and known hairs, the questioned hairs cannot be associated with the source of the known hairs. In order to conclude that two hair samples could share a common origin, it must be determined that there are no significant macroscopic or microscopic differences. It is important to determine what differences are significant because no two hairs are exactly the same in every detail (identical). It must be determined that the characteristics exhibited by the questioned sample fit within the range of characteristics present in the other sample (typically the known sample). The ideal situation is to find one or more hairs in the known sample that correspond in all respects (no significant differences) with the questioned hair.

The results of a microscopical hair comparison can be inconclusive. Situations in which an inconclusive result may be reached include, but are not limited to:

- an inadequate known hair sample
- questioned and known hair samples which exhibit both similarities and unexplained dissimilarities

- hairs which do not exhibit sufficient distinguishing microscopical characteristics (e.g., broken, fragmented, too short, colorless, opaque)

Microscopical examination of hair does not lead to unique identification of the donor. Therefore, in addition to results, the hair examiner's report may include:

- an attempt to express the significance of the finding in relation to case circumstances
- qualifying statements that further describe the strengths and limitations of the evidence
- requests for additional known samples
- a recommendation that DNA analysis be performed

There are specific guidelines with regard to Quality Assurance and Proficiency Testing. Each hair examiner should complete at least one proficiency test involving hair identifications and comparisons annually. Valid external human hair proficiency tests may not be available for purchase from an outside agency; therefore, external proficiency tests from other laboratories with hair examiners or an internal proficiency test can be used.

## **QUALITY ASSURANCE GUIDELINES**

The SWGMAT quality assurance guidelines for trace evidence were published in 2000. These guidelines provide a framework of standards for quality in the processing of all trace evidence including hairs.

Hair examiners need to exhibit knowledge of the theories, procedures, and analytical techniques necessary to produce reliable results and conclusions and have a minimum of a Bachelor's degree in a natural or applied science. Technical leaders need to have a Master of Science or doctoral degree applicable to the profession and at least five years of experience as a trace evidence examiner, or have a Bachelor of Science degree in a natural or applied science and five years of experience as an examiner, successful completion of an accepted forensic certification program or documented laboratory testing program, and successful completion of advanced course work in microscopy.

The laboratory must establish and document qualifying procedures or a training program for all hair examiner trainees. Hair examiner trainees must observe an experienced examiner handling casework prior to working cases under the direct supervision of an experienced examiner. Prior to undertaking independent casework, trainees must demonstrate competency through successful completion of the following: proficiency test(s), written and/or oral exam(s), and command of oral skills in presenting the subject in court.

As required in all trace evidence cases, a case review should be conducted by a minimum of two people. The review should consist of a technical review and an administrative

review. The hair comparison guidelines say that it is desirable that a second hair examiner verifies every microscopical hair association that may have probative value. The laboratory should have a procedure in place for resolving differences of opinion that occur during verification of a hair association.

## **STANDARDS**

Therefore, there are guidelines, if not standards, for human hair comparisons including guidelines for training, standard operating procedures, protocols, microscope maintenance and calibration, peer review, proficiency testing, quality assurance and testimony. One of the essential elements of science is peer review and it is essential in the comparison of human hair; verification and confirmation of all probative associations should be mandatory and SWGMAT guidelines require it. Hair is real evidence; it can be looked at by more than one person and should be. Several reports demonstrate the value of peer review when comparing hairs.

## **ENFORCEMENT**

Nevertheless, these standards mean nothing if there are no means of enforcement. The only enforcement today is scientific and personal integrity, ASCLD LAB Accreditation (if they enforce SWGMAT Guidelines) and the adversary process. Does ASCLD-LAB enforce SWGMAT guidelines? The American Board of Criminalistics does not enforce anything except payment of fees and counting of acquired recertification points which are like CEUs. Professional memberships (AAFS, ABC, CSFS, MAFS, etc.) can be revoked for ethics violations; but, the societies do not have any enforcement powers over the employers. Apparently no crime laboratories require ABC certification or professional memberships as a condition of employment, and the revocation is not publicized. SWGMAT has not initiated any enforcement; they have no power over anyone. In the end, there is nothing to take away from examiners or laboratories out of compliance with SWGMAT guidelines. Guidelines can simply be ignored.

## **RECOMMENDATIONS**

SWGMAT has not made any recommendations regarding hair evidence that I am aware of, except to publish guidelines. SWGMAT has not surveyed or measured anything regarding these standards. Therefore, I am on my own and do not speak on behalf of SWGMAT.

With regard to enforcement, I recommend playing the DNA card, leveraging quality with DNA, without eliminating microscopical study of hairs. All probative hair comparisons require DNA, either nDNA or mtDNA. I believe that DNA enforcement is in place through The Scientific Working Group on DNA Analysis Methods (SWGDM) and the DNA Advisory Board (DAB). Enforcement of hair comparison standards will then follow with advances in DNA standards and enforcement.

In my mind, three goals form the foundation for building a credible forensic science service: (1) honor requests, (2) speed results, and (3) minimize the inconclusive. The current state of affairs with regard to hairs meets none of these three goals. Some crime laboratories do not honor the requests of investigators who want to use hair evidence. Some crime laboratories do not speed results to those investigators so they can develop leads and solve cases. In the past, hair evidence has often left investigators with the feeling that the whole deal was a waste of time; they say, "Nothing is for sure."

What can be done? In short, not surprisingly, all crime labs need more examiners to give them time to provide quality results in a timely fashion.

A young hair examiner from one of the largest state laboratories told me that he searches clothing, processes hair samples, makes comparisons all day long, every day; but, none of those cases ever goes anywhere because they need DNA and the prosecutor never wants to pay for the DNA analysis. Why does the prosecutor need to pay for the DNA analysis? At least some of those hair cases must be of value, either to solve a crime or clear a suspect. Instead, they die in the darkness of the property room and the cases are adjudicated with confessions, bad eye-witness identifications, jail house snitches, poor attorney representation and plea bargains.

The hair examiners need to have mtDNA readily available; it needs to be free to the crime laboratory and without restrictions. The hair examiner needs to be able to send any hair they wish to mtDNA, so they can check their findings in a timely way so they can continue their investigation. Forensic science is hypothesis testing; forensic scientists need the ability to test a hypothesis and then go back in a timely fashion to test another. Are there ways to make mtDNA more readily available?

What about pyrosequencing, linear array assay, or metagenomics technology? Maybe a single sequence analysis can be accomplished within hours; multiple sample analysis can be automated. It seems, from my observations, that it is a whole lot easier than conventional sequencing and, therefore, more easily introduced into established crime laboratories. Hair evidence has sufficient value to spend the effort to look into ways to make mtDNA more available to the crime laboratories. I recommend you ask Terry Melton at Mitotyping Technologies in State College, PA for her thoughts; she has analyzed a lot of hairs for mtDNA.

## **CONCLUSION**

If mtDNA is readily available, hairs will be used as evidence and the right person will go to jail. Hair is too valuable as trace evidence to let it continue to wither in the field. Instead, I recommend the field be fertilized with research, irrigated with funding and brought back to life. Fund mtDNA research and laboratories, and thereby reinvigorate the forensic microscopists.

I hope I have addressed your charge to make recommendations for maximizing the use of forensic technologies and techniques such as hair comparisons to solve crimes and investigate deaths, and to identify potential scientific advances that may assist law enforcement in using hair as evidence to protect the public. Human hair can help do just that if given another chance.

## REFERENCES

1. Bisbing, R. E., "Hair: Microscopic Comparison," *Encyclopedia of Forensic Sciences*, Editor-in-chief, Jay A. Siegel (Academic Press Ltd., London, 2000).
2. Bisbing, R. E., "The Forensic Identification and Association of Human Hair," *Forensic Science Handbook*, edited by Richard Saferstein, Volume I, 2nd edition (Prentice-Hall, 2002).
3. Deadman, H., "The Importance of Trace Evidence," *Trace Evidence Analysis: More Cases in Mute Witnesses*, M. M. Houck, editor, Elsevier, New York, 2004.
4. Deedrick, D. W. and S. L. Koch, "Microscopy of Hair Part 1: A Practical Guide and Manual for Human Hairs," *Forensic Science Communications*, January 2004, Volume 6, Number 1, [http://www.fbi.gov/hq/lab/fsc/current/research/2004\\_01\\_research01b.htm](http://www.fbi.gov/hq/lab/fsc/current/research/2004_01_research01b.htm), 9 Dec 2003.
5. FBI, *Proceedings of the International Symposium on Forensic Hair Comparisons*, U.S. Government Printing Office, 1985.
6. Forensic Human Hair Examination Guidelines, Scientific Working Group on Materials Analysis (SWGMA), *Forensic Science Communications* April 2005, Volume 7, Number 2, [http://www.fbi.gov/hq/lab/fsc/current/standards/2005\\_04\\_standards02.htm](http://www.fbi.gov/hq/lab/fsc/current/standards/2005_04_standards02.htm).
7. Gaudette, B. D. "A Supplementary Discussion of Probabilities and Human Hair Comparisons," *Journal of Forensic Sciences*, 27 (1982) 279.
8. Gaudette, B. D. and A.S. Tessarola, "Secondary Transfer of Human Scalp Hair," *Journal of Forensic Sciences*, 32 (1987) 1241.
9. Gaudette, B. D., "Strong Negative Conclusions in Hair Comparisons—A Rare Event," *Canadian Society of Forensic Sciences Journal*, 17 (1985) 32.
10. Hicks, J. W., *Microscopy of Hairs. A Practical Guide and Manual*, FBI, U.S. Government Printing Office, 1977.
11. Houck, M. A., "Statistics and Trace Evidence: The Tyranny of Numbers," *Forensic Science Communications* October 1999, Volume 1, Number 3.
12. Houck, M. M., R. E. Bisbing, T. G. Watkins, and R. P. Harmon, "The Science of Forensic Hair Comparisons and the Admissibility of Hair Comparison Evidence: Frye and Daubert Considered," *ModernMicroscopy.com*, March 2004, <http://www.modernmicroscopy.com/main.asp?article=36>, 12 Mar 2004.
13. Houck, M. M. and B. Budowle, "Correlation of Microscopic and Mitochondrial DNA Hair Comparisons," *Journal of Forensic Sciences*, 47 (2002) 148.
14. Houck, M.M. and Bisbing, R.E., "Forensic Human Hair Examination and Comparison in the 21st Century," *Forensic Science Review*, 17 (2005) 51.

15. Kolowski, J. C., N. Petraco, M.M. Wallace, P.R. DeForest, and M. Prinz, "A Comparison Study of Hair Examination Methodologies," *Journal of Forensic Sciences*, November 2004, Vol. 40, No. 6, pp. 1253-1255.
16. Lamb, P. and L. G. Tucker, "A Study of the Probative Value of Afro-Caribbean Hair Comparisons," *Journal of Forensic Sciences*, 34 (1994) 177.
17. Lee, H. C. and P.R. DeForest, "Forensic Hair Examination", *Forensic Science*, edited by C. Wecht, Matthew Bender, NY 1984.
18. Linch, C. A., S. L. Smith, and J. A. Prahlow, "Evaluation of the Human Hair Root for DNA Typing Subsequent to Microscopic Hair Comparison," *Journal of Forensic Sciences*, 43 (1998) 305.
19. Linch, C. A., D. A. Whiting, and M. M. Holland, "Human Hair Histogenesis for the Mitochondrial DNA Forensic Scientist," *Journal of Forensic Sciences*, 46(2001) 844.
20. Linch, C.A. and J.A. Prahlow, "Postmortem Microscopic Changes Observed at the Human Head Hair Proximal End," *Journal of Forensic Sciences*, 46 (2001) 15.
21. Ogle, R.R. Jr., and M. Fox, *Atlas of Human Hair*, (CRC Press, 1999).
22. Petraco, N. and T. Kubic, *Color Atlas and Manual of Microscopy for Criminalists, Chemists, and Conservators*, (CRC Press, 2003).
23. Petraco, N., C. C. Frass, F.X. Callery, and P.R. DeForest, "The Morphological and Evidential Significance of Human Hair Roots," *Journal of Forensic Sciences*, 33 (1988) 68.
24. Robertson, J., *Forensic Hair Examination* (Taylor & Frances, London, 1999).
25. Shaffer, S. A., "A Protocol for the Examination of Hair Evidence," *Microscope*, 30 (1982) 151.
26. Strauss, M. A. T., "Forensic Characterization of Human Hair," *Microscope*, 31, 1983, pp. 15-29.
27. Wickenheiser, R. A., et. al., "Further Evaluation of Probabilities in Scalp Hair Comparison," *Journal of Forensic Sciences*, 35 (1990) 1323.

Copies of SWGMAT Guidelines are attached.

**RESPECTFULLY SUBMITTED**

Richard E. Bisbing  
 Executive Vice President  
 McCrone Associates, Inc.  
 850 Pasquinelli Drive  
 Westmont, IL 60559  
 Telephone 630-887-7100 FAX 630-887-7417  
 Email: [dbisbing@mccrone.com](mailto:dbisbing@mccrone.com)  
[www.mccrone.com](http://www.mccrone.com)